THE GEOLOGICAL RELATIONS OF THE LIGNITIC GROUPS.

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The principal lignitic areas of our country are two; one on the Pacific Coast, extending in all from Alaska to Lower California; the other in the Rocky Mountain Region, stretching from the Arctic Ocean to New Mexico. Between the Sierra Nevada and the Rocky Mountains no lignites have been discovered.

Within a few years the controversy respecting the geological relations of these lignites has become very keen, some regarding them as Cretaceous, others as Tertiary. In many instances, the conclusion reached by investigation of the flora is directly contradictory of that reached by study of the fauna. Over a considerable portion of the Rocky Mountain Region the rocks of the Great Lignitic Group are barren of animal remains and only plants are found. Where the fauna is seen the genera and species are usually Cretaceous, and where they are not clearly so they are fresh-water, and therefore of little value either way. The flora is very closely allied in general character to the Tertiary flora of Europe, many species in each being apparently identical.

During my connection with Lieut. Wheeler's Expedition, I passed over a portion of the disputed ground, and so became involved in this controversy. I have thought it necessary to study with care all the material within my reach which seems to bear upon the subject. While this study has shown me that the question at issue is by no means so simple as I supposed it to be, when I rendered my report to Lieut. Wheeler,* yet it has confirmed me in my conclusion there given, that the Great Lignitic Group, or the Fort Union Group of Hayden, is Cretaceous and not Eocene.

It is essential here to determine the value respectively of the various forms of geological evidence, for all have been cited in this discussion, and in some respects they seem to be contradictory.

In every case where applicable, stratigraphy is final. So long as we can trace a rock continuously we have no doubt of its identity. But stratigraphy in this simple form is not often available to any great extent. So variable are the rocks in large areas, owing to the different conditions under which matter may be deposited synchronously at distant localities, that direct comparisons of sections by lithological characters, or even by tracing, becomes impossible. We are compelled, therefore, to resort to palæontology in addition. Our geological column is based upon the succession of the marine invertebrata.

The stratified rocks, with the exception of comparatively insignificant portions, were deposited under the ocean, and of those which contain the remains of terrestrial organisms, by far the greater proportion was formed

* June, 1874.

along the sea-border, exposed to frequent irruptions of sea-water. The lacustrine, or purely fresh-water deposits, are small both in extent and duration, and are confined chiefly to the later portions of geological time. As the sea always covered the greater part of the earth and afforded an easy medium of migration for water-breathing animals, one would expect to find in the rocks of marine origin the most satisfactory record of changes in animal life. This would be a close record of changes in physical conditions, for animals are of a high type of organization, and, therefore, very sensitive to alteration of circumstances. The record is remarkably complete. From the base of the Silurian to the present time the gaps are few and usually of limited extent. In our country there is no group of rocks, excepting one, which does not yield a plentiful supply of invertebrate remains over perhaps the greater part of its area. Even the Triassic, usually so barren in America, is at many localities rich.

So distinct is the succession of invertebrate life, so sharp the breaks at the close of many periods in the world's history, that geologists by common consent have adopted this form of life as the foundation-stone of our system. By stratigraphy the succession of the rocks was determined, but by the succession of invertebrate life the great mass was divided into groups and geological history could be written. Rocks containing a certain fauna were called Silurian, others with a different grouping were termed Cretaceous, and others Miocene. These divisions were made on the basis of the fauna and on no other basis. This should be borne in mind.

The same succession is employed in making the minor divisions. In the Upper Missouri Region a mass of rocks is found, possessing a fauna closely resembling that of a series in Europe, termed Upper Cretaceous. This, all accept as proving that the two series occupy equivalent positions in the geological succession. Closer investigation shows that the Upper Missouri series is made up of five distinct groups, each characterized over an immense area by a peculiar assemblage of invertebrate remains. These groups make the section. If in any portion of the whole Western region we find the fossils of any one of these groups in a mass of rocks, we may legitimately expect to find the others over or under it, as the case may be. It may occur that over large areas a group thus established is perfectly barren of animal remains. This does occur in the Cretaceous groups. The Dakota Group is often barren, and can be identified only by its previously determined stratigraphical relations. The Fort Pierre and Fox Hills Groups, we are told by Dr. Hayden, show extensive zones of barrenness, whereas they are generally prolific. To explain this variation is not always easy, but we cannot do it by any assumption that the prolific portions mark the site of lagoons held by elevation and containing a few relics of a past age. In some instances these "lagoons" would involve us in difficulty, as the fossiliferous layers in different zones occupy different horizons, so that the past age, whose fauna was preserved in the "lagoons," would need to be "past" and "present" alternately for

a long period of time. The lagoon theory is quite ingenious, but unfortunately cannot accommodate itself to the facts.

Some species of invertebrates showed remarkable tenacity of life. Thus *Strophomena rhomboidalis* reaches from the Lower Silurian quite to the base of the Lower Carboniferous. *Atrypa reticularis* existed from near the beginning of the Upper Silurian to near the close of the Devonian. In each group they show marked peculiarities which almost suffice to mark the horizon from which the specimens were obtained. But no palæontologist would be reckless enough to determine a horizon with these shells as his only data. While we find instances of this kind passing upward, we have never found characteristic Carboniferous species in lower formations. But if we should, we must yield to the superior evidence. *Spirifer cameratus* associated with a strongly marked Devonian fauna in rocks occupying the Devonian position, would be a worthless witness. So, if the thing were possible, should we find *Ammonites* at a Silurian horizon, we would reject the testimony in favor of Mesozoic and accept the stronger testimony for Silurian. Even invertebrate life must yield to stratigraphy, if the two contradict.

Vertebrate life is too imperfectly preserved to be ordinarily of much service alone. The succession is not fully given. Yet it may be serviceable. If certain reptilian forms are found constantly associated with a certain invertebrate fauna, as, for example, certain forms in the Cretaceous, we may accept those as evidence where other evidence is wanting, for their horizon has been definitely fixed. This, however, applies only to marine forms. To terrestrial forms, the same objection applies as to plants. In every case, however, the horizon must be fixed for a continent, not for the world, since the conditions affecting such life may have been different in America from what they were in Europe.

Vegetable life shows no such history as to entitle it to much consideration. So patent is this fact that little use has been made of vegetable remains in determining the succession of rocks. Fucoids are worthless except in limited areas, since their organization is so low as to enable them to withstand changes which would be fatal to higher organisms. Land plants are unsatisfactory, because they are preserved in disconnected fragments, and because the areas on which they grew were so widely separated and formed so small a portion of the earth's crust. Let us look at the succession as we find it.

Until a very short time ago the existence of land plants during the Silurian and early Devonian of America was denied, and some told us why no such flora could exist. Two water-worn logs of coniferous wood, found in the Corniferous Limestone, changed our belief, but gave us little information. Respecting the flora of the Middle and Upper Devonian and of the Lower Carboniferous, we have but limited knowledge, and the localities yielding specimens are few indeed. Of the Coal Measure vegetation we know quite well that portion which grew in the swamps, but of the upland flora we have only fragmentary information, in the shape of

stray logs which floated down to the marshes. From the Carboniferous to the Trias, a great change is shown by the fossils, but we have no evidence to prove that this change is a true exposition of the actual change. For aught we can tell to the contrary, a flora closely allied to the one termed Triassic may have existed during the Carboniferous. In the Cretaceous the condition is little better. In the lower portion, leaves of dicotyledonous plants occur in prodigious numbers, but they are not of plants growing where the leaves occur. For the most part they are single leaves, washed in by streams from the land. Between this sandstone and the Lignite Group, there is an interval mostly unrepresented at the East, but at the West occupied by a mass of shales, limestones, and fine-grained sandstones, one thousand to two thousand feet thick, and absolutely barren of leaves everywhere. This was a long period, during which, under the sea, nothing but fine-grained materials were deposited. In the Lignite Group, leaves are numerous, but so far as has fallen under my observation, they are in the same condition as those at the base of the Cretaceous.

Such is the record of plant-life—a record little better than a blank, with here and there a few markings, many of which are too indistinct to be deciphered. In each horizon which yields relics of plants by far the greater portion of the area is barren—even in the Carboniferous age, how small a proportion of the rocks are leaf-bearing in the most favorable localities, while the whole vast area west from the Mississippi has yielded but a beggarly array of specimens. At best, the specimens are fragmentary. The same frond on a fossil fern, when broken up into its pinnules, may yield two or three genera and half a dozen species. When only fragments are found, it is impossible for the palæontologist to resist the temptation to make species. Describing fossil ferns from fragments, is almost as accurate work as making genera and species out of fossil teeth of sharks. In the case of leaves of dicotyledonous plants, the matter is evidently worse. The limit of variation of a species has never been approximately determined among living plants, where one has the whole tree at hand. With only imperfect and separated leaves to study, it would seem almost impossible to determine this matter respecting extinct plants.

Like vertebrate remains, vegetable relics may be made serviceable. The character of the coal flora has been so carefully studied for many years that it is quite well understood. Here, indeed, the matter in many cases is quite simple, for the roof of a coal-bed as exposed in the tunnel of a mine, not infrequently exhibits the material for the reconstruction of an entire plant. Unfortunately, attempts at re-construction are not common, and the investigator is usually satisfied to describe fragments as species, in preference to carefully studying their relation. But the horizon of these plants is now fixed, their general type is well understood, and they can be used as evidence when the animal remains are absent. The day may come when dicotyledonous plants will have been studied to

the same extent. As it is, they are of some local service. The flora of the Dakota Group serves to identify that formation at many localities, east from the Rocky Mountains when the rock is barren of animal remains. The position of this flora has been fixed by means of its position in and below rocks containing the ordinary Cretaceous types of animals.

But why do we call one flora, Cretaceous, or another Triassic, or a third, Tertiary? Simply because it is found in rocks belonging to such a group. Let it not be forgotten that we do not call the group Cretaceous, or Tertiary, because of the flora. Stratigraphy determined the general succession of rocks; animal life determined the division into groups.

The floras of our later geological eras cannot afford a satisfactory basis for generalizations looking to a determination of equivalent horizons in Europe and America. The conditions on the two continents were widely different. This general statement has been practically accepted as true by our palæo-botanists, Dawson, Lesquereux, and Newberry, all of whom have acknowledged that the testimony of plants is inferior to that of invertebrates. This story is a brief one.

In 1858, Mr. Meek and Dr. Hayden submitted to Dr. Newberry a collection of dicotyledonous leaves which they had obtained from the Dakota Group, of Nebraska. Dr. Newberry found great resemblance between these and the Tertiary flora of Europe, but regarded them as of Cretaceous age, being convinced by the stratigraphy and the testimony of invertebrate remains in the overlying rocks. Sketches of some of these were sent to Prof. Heer, who, in a letter to Mr. Lesquereux,* very positively asserted that Newberry erred in his conclusions, and that the plants are all of Tertiary forms. His language is as follows:

"It is true that I have seen only some drawings which were sent to me by Messrs. Hayden and Meek, but they are all Tertiary types. The supposed *Credneria* is very like *Populus leuce*, Ung. of the Lower Miocene, and the *Ettinghausiana* seems hardly rightly determined. Besides, it is a genus badly founded, and as yet has no value. All the other plants mentioned by Dr. Newberry, belong to genera that are represented in the Tertiary and not in the Cretaceous. And it is very improbable that in America the Cretaceous flora had the characteristic plants of the Tertiary, and this would be the case if these plants did belong to the Cretaceous."

To this the editors of the Journal append a note, stating that similar leaves had been collected by Prof. Cooke, from the base of the Cretaceous, as well as by Dr. Newberry, from the same horizon, in New Mexico, so that if the leaves are Tertiary, our Cretaceous is abolished.

Dr. Newberry replied,† stating that he had collected such dicotyledonous leaves from the Lower Cretaceous sandstones at Galisteo Creek, in New Mexico, where the Upper Cretaceous sandstones also are exposed, and at various localities further east to the Canadian river where charac-

*Amer. Journal of Sci., 2d series, Vol. 28, p. 88.

†Amer. Journ. Sci., Vol. 29, p. 299.

teristic Cretaceous 2 and 3 are seen resting upon the sandstones. This statement afforded peculiar gratification to the editor, who takes occasion in another portion of the volume to rebuke Messrs. Marcou and Heer very severely for considering these plants as Miocene. If these plants are Miocene, the editor thinks the roof of our geological house was put on before the foundation was laid. This is a very proper and judicious conclusion.

Mr. Lesquereux's rejoinder* was quite keen, defending Prof. Heer's conclusion and fully endorsing it. So that he, as well as Profs. Marcou and Heer regarded these plants and the including rocks as of Miocene age.

In 1863, Profs. Marcou and Capellini undertook a journey to Nebraska, to effect a final determination of the question. Evidently, the testimony of the plants was of little value in their eyes, for on their return they pronounced the Dakota Group Cretaceous, and not only Cretaceous, but at the base of that series as developed in America. In his work describing the leaves collected by these gentlemen, Prof. Heer confessed the superior value of the faunal evidence, and placed the leaves in the Cretaceous. In 1868, Mr. Lesquereux did the same, describing a number of *Cretaceous* plants from the Dakota Group. In this paper he announces that a remarkable generic affinity exists between the Cretaceous and Tertiary flora of America. In 1874 he published a quarto volume on the Cretaceous flora of the Dakota Group. It is sufficiently evident, then, that Mr. Lesquereux regards his plants as affording by no means positive grounds for generalization respecting equivalence of horizons in Europe and America.

Mr. Lesquereux has claimed that the determination of Miocene character, made by Prof. Heer and endorsed by himself, should not be regarded as in any way affecting the question of testimony, because the material at their disposal was so imperfect. Such a plea is unfortunate, and the excuse is worse than the error, if error it was. If the material was too imperfect to justify a positive conclusion, why was the conclusion so emphatically stated? Either the material was sufficient, or the interpreters are untrustworthy because of rashness. That the material was sufficient is clear, because the general statement of close resemblance to Tertiary forms still holds good. This whole discussion very fairly exposes the value of palæobotany as an aid in the determination of equivalent horizons on disconnected continents.

The plants of the Great Lignite Group are no better. Of these, Mr. Lesquereux has described a great number of species. Of those identified with European forms, the relations, with hardly an exception, are *Miocene*, yet they are placed in the *Eocene*. One very eccentric feature here is, that in some localities the group is Lower, and in others Upper Eocene, while the stratigraphy seems to show that both epochs may belong to the same horizon, and that the difference in the flora is local and synchronous.

*Amer. Journ. Sci., Vol. 29, p. 434.

Why the palæo-botanist should put these plants into the Eocene, rather than into the Miocene, is not known, unless it be done in deference to the stratigraphy.

Other illustrations might be given, such as the occurrence in the American Carboniferous, of types which in Europe are Triassic or Jurassic, but it is hardly necessary. It certainly seems clear to me from the showing of the palæo-botanists themselves, that the plants have nothing to do with the matter; that the fact that certain forms occur at a certain horizon in Europe is no evidence, *pro* or *con*, that their horizon in America is equivalent to that in Europe. The dicotyledonous leaves of the Lignitic Groups, *i. e.*, the Dakota and Fort Union, are locally of service, in that by them we may not infrequently trace the formation on both sides of extensive areas, from which the rock has been eroded, or in localities where the stratigraphical relations are doubtful.

It appears, then, by the common consent of all, that we must determine the European equivalents of our strata by means of animal, not by means of vegetable remains. This being understood, we may look at the facts as we have them.

The Lignitic areas are two, one on the west coast, and the other in the Rocky Mountain Region. The history of these is different, and they require to be taken up separately.

Lignites of the Pacific Coast.

According to Mr. Gabb, the lignites occur at three horizons in this region. At the lowest line are the lignites of Vancouver and the adjacent portions of Washington Territory; higher up he finds the lignites of Monte Diablo, in California. These contain all the workable lignites. But at a still higher horizon there occurs an extensive deposit of lignitic beds, none of which are of economical value. The last group he regards as of Miocene age, but the others he places in the Cretaceous.

The California lignites have been sufficiently discussed by the geologists of that State. I do not know that the reference of these to the Cretaceous has ever been seriously called in question, so that it is unnecessary to speak of them here. The deposits possessing chief interest for us are those of Vancouver. These have been carefully studied by a number of geologists, and the fossil remains, both animal and vegetable, have received close attention from palæontologists of the highest standing. The deposits of Bellingham Bay, Birch Bay, and other localities on the continent, can hardly be regarded as fairly coming within the range of this discussion, as the animal remains have not yet been worked up thoroughly.

According to Richardson, the coal deposit of Vancouver is divided into two distinct fields, one on the east coast, known as the *Nanaimo* Field; the other on the west and northwest coast, named by him the *Comox* Field. Both of these have been examined by him, but his more elaborate work was done in the latter.

The Nanaimo Field was examined by Dr. Hector, in 1859. He succeeded in working out a section of the region, which is practically as follows :*

1.	Purple clays	not measured.
2.	Conglomerate and sandstone	500 to 600 ft.
3.	*Coal*, "Douglas" seam	3 ft. 6 in.
4.	Conglomerate	60 ft.
5.	*Coal*, "Newcastle" seam	6 ft.
6.	Sandstone	about 400 ft.
7.	Conglomerate	
8.	Green sandstone	
9.	Tufaceous rock	
10.	Greenstone conglomerate	
11.	Igneous rocks	

No. 8, is richly fossiliferous, containing as determined by Mr. Etheridge, *Trigonia Emoryi, Cytherea Leonensis, Exogyra* two species, *Arca* three species, *Ostrea* two species.

The sandstone of No. 2, contains a thin coal, accompanied by plant-bearing shales. Yew-like fronds occur in the arenaceous shales associated with the larger coals.

No. 1 is a thick mass of shale somewhat variegated in color and containing great numbers of "nodules or septaria" enclosing fossils. From these nodules there were obtained *Inoceramus Crispii*, (Conrad), *I. Texanus, I. Nebrascensis, I. unduloplicatus, I. confertim-annulatus, I. mytiloides, Baculites compressus, Baculites* two species undt., *Ammonites geniculatus, Ammonites* two species undt.

Mr. Brown's† observations at Nanaimo, confirm those of Dr. Hector. In the shales accompanying the coals, he obtained great numbers of leaf impressions, both mono- and di-cotyledonous ; while from the associated sandstones, he procured various species of *Ammonites, Baculites, Inoceramus, Exogyra, Ostrea, Pecten, Arca, Trigonia, Cytherea, Psammobia, Tellina, Mactra, Natica, Rostellaria*, etc.

In the northwestern or *Comox* field, he found a grouping of conglomerates, sandstones, fire-clays, and coals similar to that observed in the vicinity of *Nanaimo*. Throughout the series there are fossiliferous beds. Dicotyledonous plants are most frequent among the leaf impressions, while among the animal remains there occur *Ammonites, Baculites, Pectunculus, Plagiostoma, Inoceramus, Trigonia, Hippurites, Astarte, Natica, and Paludina.*

Mr. Richardson‡ examined the Nanaimo field in 1871, and the Comox

*Journal of Geological Society, 1861.

†Transactions Edinburgh Geol. Society, Vol. I.

‡Reports Canada Geol. Survey, 1871–2 and 1872–3.

field in 1872. His report for 1871 is not in my possession. In the Comox field the rocks fall naturally into seven well-marked groups as follows :

G. Upper conglomerate	320 ft.
F. Upper shales	776 ft. 6 in.
E. Middle conglomerate	1100 ft.
D. Middle shales	76 ft.
C. Lower conglomerate	900 ft.
B. Lower shales	1000 ft.
A. Productive coal measures	736 ft. 6 in.
Total	4912 ft.

Below these come at once the crystalline rocks, so that the fossiliferous sandstones found below the Nanaimo coals must be absent, or, if present, overlapped by Division A.

Division A, consists of shales, sandstones, and coals, the latter very irregular. The rocks contain no animal remains, though vegetable impressions are abundant. B is made up of brownish-black argillaceous shales with thin layers of gray sandstone and arenaceous shale. The argillaceous portions are rich, both in individuals and species of animal remains. Mr. Richardson obtained *Ammonites*, 7 sp., *Ancyloceras*, 2 sp., *Inoceramus*, 4 sp., undetermined Lamelli-branchiata, 15 sp., and Natica, 1 sp.

Division C is composed of coarse pebbles, held in a brownish-gray sandy matrix, which contains wood and occasional shells. The fossils from this division are rare, as would naturally be expected, but Mr. Richardson obtained one species of *Ammonites* and one of *Arca*. Division D resembles B, but is rather more arenaceous. Thin streaks of coal are common. Lenticular patches of limestone are of frequent occurrence, and yield *Ammonites*, *Baculites*, *Nautilus*, *Ostrea*, *Inoceramus*, *Arca*, *Nucula*, together with numerous undetermined fragments of *Lamelli-branchiata* and *Gasteropoda*.

Division E is an exceedingly coarse conglomerate, and its matrix is a coarse sand. No fossils were observed in the matrix, though some were seen in the included fragments of limestone. Division F resembles D, but is much more arenaceous. Near the top it contains thin streaks of *coal* and many fragments of fossil wood, which show the structure distinctly. For the most part G resembles E, but contains no fragments of limestone. At the base it usually exhibits a mass of gray sandstone, with thin seams of coal and occasional *Belemnites*.

During 1872, Mr. Richardson examined also the deposits in the Queen Charlotte Islands, north from Vancouver. The section shows the following succession, but the groups were not measured :

1. Upper shales and sandstones.
2. Coarse conglomerates.
3. Lower shales with *coal* and iron ore.

Organic remains, both animal and vegetable, occur abundantly throughout Division 3. No. 1 is lighter colored and more arenaceous than 3. Near its base thin layers of argillaceous dolomite occur, and near the top a fossiliferous layer was found.

No doubt those readers to whom these facts are new will feel astonished to learn that any person has ever disputed the Cretaceous age of these coals. The whole trouble has arisen from the finding of some vegetable fragments which have been so far affected by prolonged maceration as to be readily identifiable with almost anything. The interpreters of these impressions are not entirely agreed among themselves.

Mr. Lesquereux* has examined a large collection of plants from Nanaimo and the adjacent portion of Washington Territory. Out of the specimens he made a number of new species, while he recognized a number identical with species previously described in Europe. So closely allied to the flora of the European Miocene are these that Mr. Lesquereux refers both Nanaimo and Bellingham to the Miocene. Somewhat later† he published a letter from Prof. Heer fortifying his position by showing the identity of several of his species with those known in Europe. Both of these palæobotanists agreed in referring Vancouver to the Miocene. The editor of the American Journal of Science felt it necessary to append to this letter an apology for Prof. Heer, in which he stated that the Professor had not had access to the paper by Meek and Hayden on the Vancouver fossils.

The collections made at Nanaimo, Bellingham Bay, and other localities in the vicinity, by Mr. Geo. Gibbs, were submitted to Dr. Newberry,‡ who regarded the Bellingham Bay deposit as most probably Miocene. He had in fact thus announced it in 1856. Some molluscan remains obtained with the leaves, induced Dr. Newberry to regard the Nanaimo coals as Cretaceous. It is evident from his language that nothing in the plants would lead one to suppose that they belong to a Cretaceous horizon, but, on the contrary, that enough was shown by them to cast doubt upon any such conclusion, were satisfactory evidence lacking. His words are as follows:

"The evidence now before us—if the specimens in the collection were obtained in the circumstances reported—shows conclusively that all the plant-bearing strata about Nanaimo are of Cretaceous age; indeed, so far as at present known to us, all the fossils collected at Vancouver's Island are of that formation."

The vegetable remains obtained at Nanaimo, in 1871, by Messrs. Selwyn and Richardson were submitted to Dr. Dawson. Among these were *Taxodium cuneatum*, Newb., *Sequoia Langsdorfii*, Heer, *Sabal*, *Palmacites*, *Populus*, *Quercus*, *Platanus*, *Cinnamomum Heeri*, Lesqx., *Taxites*, *Cupressinoxylon*.

"Dr. Dawson states that the plants led Lesquereux and Heer to refer the beds to the Miocene, but that Newberry has shown that the

*American Journal of Science, 2d series, Vol. 27.

†Ibid., Vol. 28.

‡Boston Journal of Natural History, Vol. 7.

evidence of the associated marine fossils makes them Cretaceous, which is the opinion now generally accepted, the species including *Ammonites*, *Baculites*, etc."*

The 1872 collections of Mr. Richardson were submitted to Dr. Dawson for examination. The results as announced are quite positive, somewhat contrasting in this respect with those already given.† Possibly his conclusions may have been affected by the presence of so great an abundance of animal remains. Be this as it may, his language is open to no charge of obscurity.

"The fossils from the Queen Charlotte Islands, consisting entirely of Pines and Cycads, while decidedly Mesozoic, would indicate a somewhat older stage than the others, say the Jurassic or Lower Cretaceous.

"The fossils from the coal-field of Vancouver, embracing in addition to coniferous trees, both wood and leaves of several species of angiospermous exogens, coincide with those of the Cretaceous of other parts of America, for example of Nebraska.

"The fossils from Hornby Island, in shales believed to overlie those of Vancouver Island, are also Cretaceous, and there is nothing to preclude their belonging to the upper part of that system."

It should be mentioned here that Dr. Dawson refers to the Upper Cretaceous of Europe, the only portion of that system represented in America, east from the Rocky Mountains. The Lower Cretaceous of Europe is probably represented on the Pacific Coast by the Charlotte Island coals and the Shasta Group of the California geologists.

The evidence given by the animal remains is indisputable. The coals at Nanaimo are at the horizon of the Niobrara, or Fort Pierre Group, probably not far from the dividing line. The coals of the Comox field are lower in the system; while the Queen Charlotte coals may belong to the Lower Cretaceous (of Europe), or to the Jurassic, being on about the same horizon as the Shasta Group of California.

It is certainly very strange, after the publication of facts so convincing as those given years ago by Meek and Newberry, and later by Gabb, Selwyn, Richardson, Dawson, and Billings, that Mr. Lesquereux should still maintain his original statement, as he does in the Seventh Annual Report of the Geological Survey of the Territories. It is the more remarkable because, in a volume published simultaneously with that report, he places his Miocene flora of the Dakota Group at the base of the Cretaceous for no reason except that the Dakota rocks clearly underlie others containing characteristic marine fossils of Cretaceous. This inconsistency may be explained, however, by the fact that he has seen the relations of the Dakota Group in Nebraska, while he has never visited Vancouver.

The Rocky Mountain Region.

In this region there seems to be two horizons of lignitic rocks; one at the base of the Cretaceous, extending probably from the far north in

*American Journal of Science, 3d series, Vol. 5, page 478.

† Report of Geological Survey of Canada, 1872–3.

British America southward, with more or less irregularity, into New Mexico, along the eastern and southern borders of the mountains, with an occasional lignitic bed in the interior of the region; the other reaching barely beyond our northern line into British America, and extending southward to New Mexico, covering a vast area east from the mountains, as well as within the disturbed region and beyond it at the south in New Mexico.

For a proper understanding of the conditions here, it may be well to give a brief description of the various formations as they are exposed along the east flank of the mountains.

Silurian strata rest upon the metamorphic schists, and above them come the Carboniferous, the Devonian being absent, or not satisfactorily identified. Frequently overlapping and concealing these formations, there is a very persistent mass of red beds, more or less conglomerate, and containing marls and beds of gypsum. These have been referred to the Triassic, principally, however, because of negative evidence. They are succeeded by shales containing limestone, which frequently yields Jurassic fossils. Upon this last rests the Cretaceous, of which five well-marked divisions have been ascertained in the upper Missouri region. These are, ascending,*

No. 1. Dakota Group, sandstones, shales, and lignites.
No. 2. Fort Benton Group, usually argillaceous shales.
No. 3. Niobrara Group, limestones and calcareous shales.
No. 4. Fort Pierre Group, shales with nodules of clay-iron stone.
No. 5. Fox Hills Group, sandstones, more or less calcareous.

In Colorado and New Mexico, especially in the latter territory, it is not always possible to make out the groups accurately, and some of those who have worked in that region are satisfied to use the following classification:

Lower Cretaceous, equivalent to No. 1.
Middle Cretaceous, equivalent to Nos. 2, 3, and 4.
Upper Cretaceous, equivalent to No. 5.

The lower Cretaceous yields animal remains at few localities, and these, in many cases, are of such a character as to render its reference to the Cretaceous a somewhat doubtful one. It contains vast numbers of vegetable impressions, strikingly resembling the Miocene flora of Europe.

The Middle Cretaceous is quite variable in composition, but there are few exposures of the lower portions which will not yield fine collections of animal remains. The ferruginous nodules of the upper part are invariably fossiliferous. It occasionally contains thin beds of lignite, one having been observed at Sage Creek, Wyoming Territory, by Dr. Hayden, and a similar one at Cañon City, Colorado, by myself.

The upper boundary line of No. 5, is very indefinite. Indeed it is the matter in dispute. The rock is sometimes a rusty arenaceous shale but

* This succession was elaborated by Mr. Meek and his co-laborer, Dr. Hayden.

ordinarily a not very compact sandstone, rusty yellow in color and concretionary in structure. In parts it is calcareous, and where it shows such a composition, is very fossiliferous. Dr. Hayden notes the interesting fact respecting the Fort Pierre and this group, that there are zones or belts in which they are almost non-fossiliferous. This feature, observed in the Upper Missouri Region, I found to be quite characteristic of the Upper Cretaceous in Colorado and New Mexico. The group is marked by a rich fauna, largely of Cretaceous forms, but mingled with many types of more recent character.

Above the unquestioned Cretaceous, there comes the great lignite series, termed by Dr. Hayden, the Fort Union Group. This is an immense mass of sandstones, shales, and beds of lignite, having a maximum thickness of not far from four thousand feet. Marine organic remains are commonly found in the lower portions, but over a part of the area, as one ascends in the series, he finds the traces of marine life disappearing, while land and fresh-water shells occur associated with vast numbers of leaves of dicotyledonous plants. The northern and southern portions of this group have never been joined by direct tracing. At the north it underruns the White River Group near Fort Fetterman. From that point southward it is concealed for about three hundred miles, re-appearing from under the same group in Colorado, twenty miles south from Cheyenne. A careful study of Dr. Hayden's reports leaves no room to doubt the correctness of his conclusion that the formation near Fort Fetterman and that south from Cheyenne are the same.

The Lower Lignitic Group.

For convenience in this connection I thus designate the Dakota Group, Cretaceous No. 1. This yields lignites over an enormous area, reaching from the Arctic Ocean into New Mexico, but for the most part the beds are thin and the lignite itself is very impure.

The only detailed reference to this group in *British America*, which I have at hand is that of Dr. Hector.* Sir J. Richardson's "Journal of a Boat Voyage through Prince Rupert's Land," is not within my reach, and his statements in the Appendix to Franklin's Expedition are very unsatisfactory. Dr. Hector's observations were made upon the Saskatchewan River and its tributaries. He found a well-defined series of coal-bearing strata on the North Saskatchewan, or Red Deer River, and on Battle River. On Red Deer River he obtained the following section, descending,

1. Sandstones and dark clays.
2. Banded marlites, clays, and limestones.
3. Shell conglomerate.
4. Clay.
5. Banded clays with clay-iron stone.
6. *Coal*, three feet thick.
7. Clays.
8. Silicified wood and brown coal.
9. Sandy clays.

Total thickness of section, 600 feet.

* Journal of the Geological Society, 1861.

The shell-conglomerate contains vast numbers of *Ostrea cortex*, while the overlying banded clays exhibit *Ostrea cortex*, *O. vellicata* and *Cytherea Texana*, and one of the limestone layers yielded *Ostrea anomiæformis*, *Mytilus*, 2 sp. *Cardium multistriatum*, *Crassatella*, *Venus*, *Rostellaria*, and *Paludina*. In tracing this group from Red Deer to Battle River no change was observed in the section, but at the latter locality, and somewhat higher in the series, a concretionary sandy limestone was found containing *Avicula*, *Cardium*, *Cytherea*, and *Baculites compressus*.*

On the North Saskatchewan the relations of the coals are not shown fully beyond cavil. In that region the formation was traced over a great extent of country and diligently searched for fossils, but without much success. The coals underlie a mass of variegated marly clays, many of them containing comminuted fragments of vegetable matter. These are similar to those of the Red Deer section. In the immediate vicinity of Fort Edmonton, on the North Saskatchewan, there are found fragments of silicified wood, the same as those occurring near the base on Red Deer. In the absence of the higher and fossiliferous strata, Dr. Hector regards the silicified wood and the remarkable lithological resemblance as proving the identity of the two sections as far as compared.

East from the Rocky Mountains, within the United States, the lignite of this group is small in quantity and of very poor quality. A number of localities have been given by Dr. Hayden and others. The lignite is never really workable; and, except at one locality in Wyoming, mentioned by Dr. Hayden, it is not useful for fuel. At one locality, midway between Denver and Colorado Springs, in Colorado, I saw a deserted opening upon a thin bed. It had proved of no value.

In the interior of the Rocky Mountains this group seems to carry lignite very rarely. Prof. Marsh, in 1870, discovered a bed of coal on Brush Creek, a tributary of Green River. Overlying it is a sandstone containing a layer full of *Ostrea congesta*, and further up, another which yielded a crinoid, evidently allied to *Marsupites*. Below the coal, coprolites, cycloidal scales of fish, together with teeth resembling *Megalosaurus* were found. This locality was afterwards visited by Mr. Emmons, who ascertained that the rocks belong to Cretaceous, No. 1.

I regret that the reports of Messrs. Gilbert and Howell to Lieutenant Wheeler are still unpublished. They contain important details respecting the distribution of the lower lignitic series. The report of Dr. Newberry upon the San Juan Expedition has never been printed. It thus happens that, although a large portion of New Mexico has been very closely examined, none of the results are accessible except those obtained by Dr. Newberry on the Ives Expedition and by Dr. J. L. Leconte in 1868.

Dr. Newberry† found this group at many localities in New Mexico, carrying thin beds of lignite. At Camp 92, there is an alternation of

* These fossils were identified by Mr. Etheridge.

† Ives' Expedition. Report on Geology, pp. 81, 85, 87, 89, 94.

coal and shale, twelve feet thick, resting almost directly upon Triassic marls, and underneath a yellowish sandstone filled with dicotyledonous leaves. At Camp 96, and at Oraybe, he found above this bed, green and blue shales two hundred and fifty feet thick. Toward the base this series contains *Ammonites percarinatus*, *Inoceramus Crispii* and *Gryphæa navia*, while toward the top it shows *Pinna* (?) *lingula*, *Gryphæa Pitcheri*, with beds of lignite, above which are impressions of *Platanus*, *Alnus*, *Quercus*, etc., along with *Sphenopteris*. From the Moqui country eastward for about twenty miles, these beds are continuously in sight; but, at length, they under-run a mass of Tertiary rocks, which Dr. Newberry thinks may prove equivalent to the White River Group of the Upper Missouri Region. At Camp 100, beyond the eastern border of this Tertiary basin, a group of lignites and brown sandstones is found between the Triassic and Cretaceous, but it is not persistent. Near Fort Defiance, the Lower Cretaceous Series is seen resting on the Triassic and consists of "green and dove-colored shales, brown and greenish sandstones, brownish-yellow concretionary limestone containing *Gryphæa Pitcheri*, and beds of lignite." The section here is about the same as at Oraybe. At Campbell's Pass, the section is as follows:

1. Cretaceous sandstones, shales, and lignites..... 700 ft.
2 and 3. Marl Series.. } .... 750 ft.
4, 5, and 6. Salt Group } Triassic. ..... 520 ft.
7. Carboniferous limestone.

The shales in No. 1 contain *Gryphæa Pitcheri*.

The same section was traced by Dr. Newberry directly to the Rio Grande, and at Galisteo Creek, not far from Santa Fe, the section is:

1. Cretaceous sandstones and shales with beds of lignites.
2. Red and white marls, all somewhat indurated, with silicified wood.
3. Soft red sandstones of the Salt Group.

Above these are the Santa Fe marls which rest unconformably upon the Cretaceous.

Dr. J. L. Leconte's notes* give few details respecting this region, but they serve to confirm the earlier observations by Dr. Newberry.

In 1869, Dr. Hayden visited Santa Fe and its vicinity. His notes are given in his report for that year. The section obtained by him at Santa Fe is certainly eccentric. On Galisteo Creek, he identifies No. 2 and 4 of the Cretaceous. The remainder of the section is as follows, ascending,

1. *Coal Group*, with abundant impressions of deciduous leaves, resting conformably upon well-marked Cretaceous strata.

2. *The Galisteo Sand Group*, consisting of variegated sands and sandstones, overlying conformably the *Coal Group*, and concealing it on the east and northeast flank of Placière Mountain. This group shows peculiarities here, not seen in the lignite series elsewhere. The color varies

*Notes on the Geology of the Smoky Hill Route.

from light-red to deep brick-red, dull-purplish, deep-yellow, white, brown, drab, etc. The only fossils are silicified trunks of trees.

3. *Santa Fe Marls*, which rests unconformably upon the Galisteo Group, and are of much later date.

Dr. Hayden of course refers this whole section to the Tertiary. Mr. Lesquereux does the same, in consideration of six species of leaves, four of which are peculiar to the locality, and two occur elsewhere, also. But a careful comparison of this section as given by Dr. Hayden, with the details of the geology along Dr. Newberry's route from Santa Fe westward, as given in Ives' report, will, I think, satisfy anybody that Dr. Hayden has by some oversight inverted the order, and that the Galisteo Group *underlies* the Coal Group. The Galisteo Group is unquestionably the Triassic, as abundantly appears from the descriptions of that system in New Mexico, by Newberry and Leconte.

In Utah and New Mexico, Messrs. Gilbert and Howell have found coal beds of much economical value at about the horizon of this group, but their work, being unpublished, is not accessible.

The Upper or Great Lignitic Group.

This is the *Fort Union Group* of Dr. Hayden. Its relations to the Upper Cretaceous are so intimate that the description of the one requires constant reference to the other.

This group, so far as our present knowledge extends, seems to pass but little beyond our northern boundary. For information respecting its character at the north, I have consulted the writings of Messrs. Hayden, Meek, Lesquereux, and Emmons, while for the southern extension in Colorado and New Mexico, I have drawn from the observations of Hayden, Lesquereux, Leconte, Cope, and myself.

Dr. Hector observed some lignites at La Roche Percée, not far north from the United States boundary line, which he regards as the northern extension of the Missouri lignite basin, and therefore places them in the Tertiary, though he thinks they may possibly be Cretaceous. Prof. Hind thinks that they belong to the Fox Hills Group of Meek and Hayden.

Throughout the *Upper Missouri Region*, this Lignite Group is perfectly conformable to the Upper Cretaceous, and the line of separation cannot be determined. During many years of exploration, only one case of unconformability, that between Spring Cañon and Bridger Peak on Laramie Plains, has been found.

On the Yellowstone, below the mouth of Big Horn River, the Upper Cretaceous (5) passes upward into a dark-gray sandstone, containing many Cretaceous species. This, in turn, changes into a coarse-grained friable ferruginous sandstone, containing many concretions. This latter rock yielded a few indistinct bivalves, which were evidently of marine origin. At a locality between Big Horn and Powder Rivers, No. 5 is composed of clay and marls, with layers of concretionary, ferruginous, calcareous sandstone, containing several Cretaceous species. It passes almost imper-

ceptibly into the Lignitic Group above. On Powder River one of the lower sandstones of the latter group has layers hardened by the presence of calcareous matter, so that the rock weathers into architectural forms, the pillars being protected by a cap of the harder rock.

On Gardiner's River the intimate relations of the two groups are well shown. At one locality, where 1200 feet of strata, belonging to them are exposed, it seems impossible to draw any line of division, "this great group of beds, simply alternate beds of sandstone and arenaceous clays, passing down into the dark sombre clays of the Cretaceous." At Cinnabar Mountain, above the mouth of Gardiner's River, "the dark, laminated clays of the Cretaceous, passing up into the Upper Cretaceous, are well shown with perfect continuity, then passing up into a great thickness of the sombre brown sandstones of the Coal Group. There is a great uniformity between the Upper Cretaceous and Tertiary series. We can detect some variations in color and texture, but they are of minor importance and could not easily be described in words."*

On Box Elder Creek, not far from Fort Fetterman, the lignite series consists of rusty sands and sandstones and arenaceous clays, with some seams of lignite. On Deer Creek, twenty-seven miles from the Fort, the black clays of No. 4 are capped by a thin bed of ferruginous arenaceous clays, above which are two beds of sandstone. The lower one of these is concretionary throughout, being filled with sandstone concretions imbedded in an indurated clay, which also shows a tendency to concretionary structure. In the harder portions, a few specimens of *Baculites*, *Inoceramus*, etc., were found. The upper bed has a similar rusty-yellow color, but yields no fossils. Both rocks, but especially the lower one, tend to weather into architectural forms. Near old Fort Casper a yellow ferruginous sandstone, containing *Inoceramus* and huge concretions, is seen resting on black shaly clays which Dr. Hayden assigns to the horizon of Cretaceous, No. 2.

On the North Platte River, from Sage Creek to Medicine Bow, and thence to Bridger's Pass, the sandstones and the associated clays lying at the base of the Lignite Group, are almost continuous. They rest directly upon Cretaceous clays. The sandstones are irregularly concretionary and occasionaly yield an *Inoceramus or Baculites*. Some rusty calcareous beds contain *Ostrea*. Along the Platte, four beds of the sandstone can be distinguished. The first, second, and third, beginning at the base, are in all fifty to eighty feet thick, drab-brown, and quite massive. The fourth is yellowish-gray, full of large rusty-brown concretionary masses, which are laminated, and in reality are arenaceous limestones. Between the beds are thin layers of sandstone and sandy limestones. At Cooper's Creek the rusty arenaceous beds of No. 5 pass up gradually into the coal-bearing layers without any perceptible break, and without any marked change in the sediment. The latter series is from 1500 to 2000 feet thick and consists of rusty-yellow sandstones, alternating with greenish-gray

* Hayden. Report for 1871, p. 62.

indurated sands and clays. In the neighborhood of Fort Steele the sandstones, seen at Medicine Bow, are found resting on Cretaceous clays, and passing up into the coal-bearing strata. These contain a characteristic fucoid, which Mr. Lesquereux has designated by the name of *Halymenites major*.

Along the Union Pacific Railroad, from Como to St. Mary's, nearly fifty miles, the lignitic rocks prevail and the heavy sandstone at the base is traceable to Carbon, where a coal overlying it is mined. This is the fucoidal or lignitic sandstone, showing the fucoid just referred to. The overlying rocks contain vast numbers of deciduous leaves. Beyond Rawlings' Springs this series is again seen, overlying Cretaceous clays, and at Separation a coal, probably the same as at Carbon, is worked. At this locality leaves and fresh-water shells are found in the upper portion of the group which appears to be not far from two thousand feet thick.

From Separation to Bitter Creek Station horizontal Tertiary beds prevail, but occasional borings have demonstrated that the coal-strata are not deeply buried. These Tertiary beds are of fresh-water origin and contain *Unio*, *Melania*, and other fresh-water species. They are unconformable to the lignite series and occupy a synclinal trough formed by these rocks.

According to Messrs. Meek and Bannister, there occurs between Bitter Creek Station and Green River an enormous accumulation of coal-bearing rocks, not much less than 4000 feet thick, and underlaid by about 1000 feet of sandstone. The greater portion of the upper series is clearly of brackish-water origin, as it contains layers at various horizons, from which *Ostrea*, *Corbula*, *Melania*, and *Goniobasis* were obtained. Many layers are rich in deciduous leaves, and from one in the upper portion of the series the remains of a saurian were obtained. These were afterwards described by Prof. Cope, under the name of *Agathaumus sylvestris*. Before reaching Green River, these rocks under-run, unconformably, a later series, known as the Green River shales.

Messrs. Meek and Bannister made no examination at Point of Rocks. At this locality Mr. Lesquereux found an anticlinal which exposed the shales of Cretaceous, No. 4, underlying conformably the great fucoidal sandstone. This rock is 185 feet thick, and contains *Halymenites major*, Lesqx. This sandstone has a striking lithological character, which is widely persistent in the Rocky Mountain region. It is a little strange that these Cretaceous rocks do not appear under the Bitter Creek series at Salt Wells, where Meek and Bannister found the great mass of sandstone.

From Green River westward to Bear River the coal rocks are not seen, and the same is true respecting the region between Bear River and Coalville. These areas seem to be utterly isolated. Mr. Emmons finds them surrounded on all sides by the Tertiary beds in such a way as to prevent any junction by stratigraphy with other areas.

At Bear River, the strata have been so distorted that it is not easy to

construct a satisfactory section, but on Sulphur Creek, a tributary of Bear River, Messrs. Meek and Bannister found exposures affording an interesting series of disconnected sections. The following shows the succession, ascending, as far as it seems to have been worked out satisfactorily :

1.	Shales and sandstones, not well exposed, about.....	500 ft.
2.	Two or three rather heavy beds of yellowish-gray sandstone, with some clays. Near the base, two layers of sandstone occur, containing *Ostrea soleniscus*, *Trapezium micronema*, etc., about.....	100 ft.
3.	Greenish and bluish-gray sandy clays and some dark shale.....	100 ft.
4.	*Coal*.....	7 ft. 6 in.
5.	Massive sandstone, light-colored, with sandy clay at base.....	95 ft.
6.	Sandstones, clays, and arenaceous shales.....	275 ft.
7.	Not exposed, a horizontal distance of about.....	2100 ft.
8.	Light-gray sandstones and clays, including a *Coal bed*, 7 ft. 6 in., sandstone, over coal, containing *Inoceramus problematicus*, *Cardium* and undetermined univalves.....	150 ft.

At Coalville, in Utah, the same gentlemen obtained the following magnificent section. The order is ascending :

1.	Sandstones, clays, and arenaceous clays.....	163 ft.
2.	Clays and thin sandstones, with *Inoceramus problematicus*, *Cardium subcurtum*, *Lucina*, *Macrodon*, *Modiola multiliniyera*, *Corbula*, *Arcopagia*, *Martesia*, *Neritina pisum*, *Turritella*, etc.....	150 ft.
3.	Clays and sandstone.....	80 ft.
4.	*Coal*.....	13 ft.
5.	Yellow-gray sandstones, roof of coal, containing *Inoceramus* and *Ostrea soleniscus?*.....	25 ft.
6.	Very dark clay with *Inoceramus problematicus*.....	80-100 ft.
7.	Clays and sandstones, not well exposed.....	100 ft.
8.	Sandstones, rich in fossils, *Halymenites major*, *Avicula*, *Cardium*, *Trapezium*, *Tellina*, etc.....	100 ft.
9.	Clays and sandstones.....	80 ft.
10.	Clays and sandstones, with *Ostrea soleniscus*, *Avicula*, *Cardium*, *Tellina*, *Arcopagia*, *Gyrodes*, *Cyprimera*, etc.....	190 ft.
11.	Clays, sandstones, and some conglomerate.....	250 ft.
12.	Not well exposed, shales and clays.....	600 ft.
13.	Shale and sandstone.....	37 ft.
14.	*Coal*.....	2½ ft.
15.	Clays and some sandstone, with mixed fauna, *Anomia*	

	Inoceramus, Unio, Cardium, Cyrena, etc.	48 ft.
16.	*Coal*	5½ ft.
17.	Concealed	60 ft.
18.	Massive sandstone	220 ft.
19.	Sandstone and sandy clay with *O. soleniscus*	14 ft.
20.	Sandstones and clays, not fully exposed	775 ft.
21.	Gray sandstone, with *Inoceramus, Cardium, Ostrea*, etc.	30 ft.
22.	Sandstones and clays, with fragments of *Ostrea*	191 ft.
23.	Concealed	380 ft.
24.	Conglomerate, more or less coarse	860 ft.
25.	Great Echo Cañon Conglomerate, more than	700 ft.

Mr. Meek is inclined to regard this whole section below No. 25, as not only Cretaceous but as belonging to the Middle Cretaceous, not higher than No. 3. This conclusion appears to be quite improbable. This, it is true, lies very near the western shore-line of the Cretaceous sea, for no rocks belonging to that system have been found west from the Wasatch Mountains at this latitude, which explains sufficiently the coarseness of the sediments toward the base of the section. It certainly seems proper that all above No. 6 should be placed in the Upper Cretaceous, for the fauna approximates the fauna of that horizon. The succession of the rocks below No. 6 fully favors this view.

Mr. Emmons, who has studied this region elaborately, maintains that the Coalville and Bear River areas are but fragments of the great lignite series seen further east, and that they are the western portions of the Bitter Creek Group. That the Coalville section above No. 6, is equivalent to the Bitter Creek Group, and therefore to the Fort Union Group, is rendered very probable when we consider the enormous thickening of the rocks, shown alike by both sections, the general lithological resemblance, and the presence of the fucoid, hitherto unknown below that horizon. Of Mr. Emmons' work nothing has been published, except a brief resumé in Volume III, of Mr. Clarence King's reports. Mr. Lesquereux regards the two groups as practically equivalent.

Returning now to the east face of the mountain, we reach the *Colorado* and *New Mexico* portion of the area, about twenty miles south from Cheyenne. In Colorado and eastern New Mexico, the Lignitic Group shows the following section:

1. Sandstones, yellowish, ferruginous, more or less conglomerate.
2. Sandstones, shales, and *coal-beds*. The sandstones, gray to light-yellow.
3. Sandstone, rusty-red to yellow, brown, and gray, containing thin *coals*, more or less concretionary, and passing downward into a mass of clays and argillaceous sandstones.

In many localities the clays and argillaceous sandstones seem to be almost absent, but where the section is complete, as at Cañon City and

Colorado Springs, they form a perfect and imperceptible transition from the Sandstone No. 3, downward to undisputed Cretaceous. With possibly one exception, the Lignitic and Cretaceous series are everywhere perfectly conformable. Mr. Marvine found distinct unconformability between them in Middle Park near Mt. Bross; but this must be quite local, for Dr. Hayden states respecting Middle Park, in the same vicinity, that the Tertiary rocks are found in great thickness and perfectly conformable to the underlying Cretaceous. At many localities east from the mountains a conglomerate occurs resting unconformably upon the lignitic rocks.

About twenty miles south from Cheyenne, this group is exposed. The Cretaceous passes up imperceptibly into the fucoidal sandstone, which is ninety-five feet thick. At a few feet above the sandstone is a coal-bed, four to six feet thick, roofed by clay, containing an oyster like *O. subtrigonalis*. On Boulder Creek, the same *Ostrea* is found above the coal. Near Golden, the sandstone is separated from the Cretaceous beds by only a few inches of clay, and contains dicotyledonous leaves along with *Halymenites major*. Near Colorado Springs this rock contains a a variable seam of coal, and affords the fucoid and dicotyledonous leaves. Below it are layers of clay and shale, yielding *Baculites* with other Cretaceous forms, and passing downward into Cretaceous dark shales.

In the vicinity of Cañon City, on the Arkansas, the succession is clearly shown. The dark Cretaceous shales gradually merge into a mass of clay and argillaceous sandstones which passes upward imperceptibly into the fucoidal sandstone. In the upper portion of this loose-grained rock there are many impressions of fucoids and, in some of the more compact layers, indefinite impressions of mollusca. In the upper portion of the clay-beds Dr. Hayden found an imperfect *Inoceramus*. From this locality southward, the sandstone is easily followed, standing out like a wall for long distances. Near Trinidad, on the Purgatory River, Mr. Lesquereux found it 200 feet thick, resting on the dark shales of the Middle Cretaceous. On Raton Creek it is 178 feet, resting on the Cretaceous shales, and overlaid by 300 feet of coal-bearing rocks. On Vermejo Creek, the sandstone contains three thin seams of coal. At Cañon City it contains certainly two.

Respecting the relations of the Cretaceous and the Lignitic Group, east from the mountains, Dr. Hayden says, "These black shales pass gradually up into rusty arenaceous clays, which characterize No. 5; and No. 5 passes up into the Lignite Tertiary beds, where they can be seen in contact, without any well-defined line of separation that I could ever discover."*

In its southern extension and near the mountains the fucoidal sandstone is for the most part of a texture unfavorable to the preservation of organic remains and seldom contains any other than very rude specimens of fucoids. Dr. Hayden states, that he has searched it over an area of many miles, but has succeeded in finding no fossils excepting "one

* Reprint of Reports, p. 121.

obscure fragment of a marine bivalve, like the clam, while in the mud-beds and shales below, species of *Inoceramus* are common."* In the Raton Pass, Dr. Leconte found a small *Inoceramus*, badly preserved, as would naturally be expected by any one familiar with the rock. Major Hawn, in his report to Lieut. Ruffner, says that he obtained Cretaceous fossils near Cañon City at only a few feet below the coal. Above this sandstone, in the shales among the coal-beds, there are several layers crowded with an *Ostrea* of undetermined species.

Along the South Platte, about forty miles north from Denver, there occurs a great mass of sandstone which, in my report to Lieut. Wheeler, I have regarded as the great fucoidal sandstone. Mr. Arnold Hague, who explored this region with much care in connection with the Geological Survey of the Fortieth Parallel, maintains that the sandstones belong not at the base, but at the very top of the Lignitic Group. He is doubtless correct. The section, as I followed it, begins at the mouth of St. Vrain's Creek and continues without a break to Evans and Greeley, a distance of about twenty miles. The dip in this direction is quite small, as the road crosses the true dip. My examination here was a hasty one, and I had no opportunity to follow up either St. Vrain's or Thompson's Creek, so as to ascertain what underlies this rock. The whole mass certainly overlies the thin lignites of Platteville. The clays and sandstones seen below the sandstones at the mouth of St. Vrain's bear much resemblance to those below the fucoidal sandstone at Cañon City, and this induced me to regard the section as the same. But a careful comparison and summing up the sections, shows me that the total thickness, several hundred feet, is far too great to permit us to suppose it the fucoidal sandstone, and we must therefore regard it as belonging much higher in the series.†

These sandstones are several hundred feet thick, light-bluish-gray to reddish-brown and yellow, and rest on a mass of clays and shaly sandstones. They are all friable and yield readily to the weather, wearing into immense cavities and breaking down into loose sand. In the reddish ferruginous sandstones, which form the *top* of this group, there are many thin argillo-calcareous layers, which are prodigiously rich in fossils. Some of these are simply masses of the fucoid, *Halymenites major*, Lesqx, while others contain characteristic species of Cretaceous No. 5, such as *Ammonites lobatus*, *Cardium speciosum*, *Nucula cancellata*, *Mactra alta*, *Mactra Warrenana*, *Lunatia Moreauensis*, and undetermined species of *Anchura*. The same species were obtained from this vicinity in 1874, by a party under the direction of Dr. Hayden, to whom I had minutely described the locality.

From the interior of New Mexico we have but little information respecting this group. Much material has been gathered, but it is unpub-

* Reprint of Reports, p. 154.

† I understand that Dr. Newberry proposes to visit Colorado this year. He will examine this vicinity closely.

lished. Prof. Cope* has given a brief statement of its relations in the region northwest from Santa Fe, and lying between the Chama and San Juan Rivers. This region had been visited previously by Dr. Newberry in 1859, and by myself in 1873, but the trails followed merely crossed the region, and only skirted that portion referred to by Prof. Cope. The Tertiary lake mentioned by Prof. Cope is evidently the same with that crossed by Dr. Newberry, when with the Ives Expedition. The Cretaceous here consists of *Lower Cretaceous*, sandstones, *Middle Cretaceous*, mostly dark shales and limestones, *Upper Cretaceous*, sandstones. Throughout the whole series Cretaceous species occur. In the Upper group *Ammonites*, *Baculites*, and other indisputable forms occur in great abundance, associated with *Halymenites major*. The following is Prof. Cope's statement:

"The shore of this lake was formed by rocks of the Cretaceous formation of an age near the No. 3, of Meek and Hayden. In approaching it from the east we traverse the sandstones of Cretaceous No. 1, both horizontal and tilted at various angles, and find No. 2 resting upon it, frequently unconformably, and tilted at higher angles, frequently 45°, sometimes 50°, to the west and southwest, and containing numerous fossils, as *Inoceramus*, etc. The upper sandstones of this formation pass into a brackish or fresh-water formation, which includes a bed of lignite, of sometimes 50 feet in thickness. Above this rests, conformably, where seen, a moderate thickness of rather soft marine rocks, containing numerous shells, *Acephala*, *Gasteropoda*, and *Cephalopoda*, including *Oysters*, *Baculites*, and *Ammonites* resembling *A. placenta* most, with sharks' teeth. Resting unconformably upon these, with a much reduced dip, is a mass of brown and reddish sandstone, some 1500 feet in thickness, inclining perhaps 10° south and southeast. These pass continuously into the superincumbent red and gray marls, alternating with brown and white sandstones of the fossiliferous beds of the Eocene. The observed part of these beds is about 1500 feet in depth."

Having been within not more than fifteen miles from the verge of the Eocene basin, I feel assured that Prof. Cope is inaccurate in his reference of these rocks to Nos. 1, 2, and 3, of the Cretaceous. They are the Lower, Middle, and Upper divisions of the Cretaceous and represent the whole series.

Prof. Cope's mistake was a natural one in his circumstances, as he had devoted no time to the study of the Cretaceous in New Mexico, though he had examined that formation quite closely at the north.

Respecting the geological position of this group there has been great difference of opinion. On one side the statements have been for the most part very positive, while on the other they have been uncertain and more or less compromising. Those who have studied the plants, throw the beds into the Tertiary, while those who have studied the fauna and the stratigraphy regard the greater portion of the mass as Cretaceous though

* Lieut. Wheeler's Report of Progress for 1873. Appendix.

they are generally inclined to admit that the highest portions may be Eocene.

After a careful study of plants collected by Dr. Hayden in the Upper Missouri Region, Dr. Newberry referred the Fort Union Group, as there exhibited, to the Miocene. This conclusion was based upon the close resemblance of this flora to the so-called Miocene flora of Greenland and its intimate relation to the Miocene flora of Europe. Dr. Newberry still holds this opinion respecting the Upper Missouri Region, though he shows some inclination to dispute the assertion, that the southern portion is as recent as the Eocene. The stratigraphical evidence, however, is so strong to prove the identity of the group throughout the Rocky Mountain Region, that all parts of the area must belong to the same horizon. If one part is Miocene the other is Miocene also.

Mr. Lesquereux has published several elaborate and very able papers upon the flora of this group. Though it has close affinity to the Miocene flora of Europe, he does not regard it as Miocene throughout, but divides the series containing it into Upper and Lower Eocene, the former represented at *Carbon*, *Evanston*, and *Sage Creek*, and the latter at *Raton Mountains*, *Golden*, *Black Butte*, *Spring Cañon*, and *Fort Union*. As a whole, he regards this vegetation as Oligocene. Above the Lignitic Group he finds the Miocene at *Green River*, *Elko Station*, *South and Middle Parks*.

Dr. Hayden has long halted between two opinions. He looks upon the Coalville and Bear River sections as Cretaceous beyond doubt, but concerning the rest of the Great Lignite Group he is by no means so decided. Sometimes he speaks of the Lignite Tertiary, at others he seems to regard the group as partly Cretaceous and partly Tertiary, while for the most part in his more recent publications he is disposed to regard the whole as, in great measure, beds of transition. From the beginning his inclination has been to favor the Tertiary hypothesis. Under such circumstances one cannot fail to admire the frankness with which all the facts are given in Dr. Hayden's reports, many of them bearing directly against the deductions previously published by the Doctor himself. Judging from his readiness to receive the truth even at the expense of discarding cherished opinions, there is every reason to hope that before very long Dr. Hayden will be one of the most energetic expounders of the doctrine that the Lignitic Group is Cretaceous.

Mr. Meek refers the Coalville and Bear River areas as well as a portion of the Bitter Creek Series to the Cretaceous but thinks the upper portion of the Bitter Creek section may be Tertiary. He is quite positive that the Black Butte portion of the section is Cretaceous; but this lies far up in the series.

Prof. Cope is very positive respecting the Cretaceous age of the Black Butte section, because *Agathaumus sylvestris* occurs there. Prof. Marsh is equally positive regarding some other localities. Dr. Leconte, Mr. Arnold Hague, and myself have referred the Colorado beds to the Cretaceous.

CONCLUSIONS.

As the Lower Lignitic Group underlies a great mass of strata, containing abundance of Cretaceous species, its geological relations have long been regarded as definitely settled. For precisely the same reason there is no longer room for dispute respecting the Vancouver beds.

In the matter of the Great Lignitic Group the evidence is not so easily obtained as in the other cases, nor, when obtained, is it so absolutely convincing as to stop all discussion. Looking over the facts already given, one finds

First, That the Cretaceous, No. 5, and the Great Lignite Group are everywhere comformable to each other, and that the latter is conformable within itself and unconformable to the fully recognized Tertiaries above it. In an area of many thousands of square miles, which has been closely examined in almost all its parts, only two instances of unconformability between the groups have been recorded, both of which are very local, while one of them is, to say the least, of uncertain existence.

Secondly, That from the beginning of Cretaceous, No. 5, to the close of the Great Lignite Group, there was no change in the general conditions, which would be of more than merely epochal value. The Upper Cretaceous (No. 5), is a rusty yellow sandstone, usually concretionary when compact, which passes upward imperceptibly into the rusty-yellow sandstones at the base of the Lignitic Group, themselves more or less concretionary. Ordinarily the gradation from one to the other is so perfect that they cannot be separated. At few localities indeed is it possible to define any line of separation. In Colorado, the fossils of No. 5 are usually absent from the lower sandstones, so that the Lignitic Group appears to rest directly upon the shales of the Middle Cretaceous. The only fossils characteristic of No. 5, ever obtained from Colorado, were procured from rocks, which are most probably among the very highest strata of the Lignitic series.

The variation in character of the strata above the fucoidal sandstone, giving us shales, sandstones, coal beds, and local limestones, is hardly sufficient to be of even epochal value. The marine conditions remained the same, for the fucoid *Halymenites major* passes through the series, and the land conditions could have undergone but little change, for of the plants, whose leaves occur in the great sandstone, many occur higher up in the group. The sandstones themselves exhibit a very remarkable resemblance to each other. The changes in structure are no greater or more abrupt than those in the Coal Measures. It is quite evident that the relations of the great sandstone (in which I include also that portion termed Cretaceous, No. 5), to the main series of lignites, is precisely the same with that held by the Conglomerate to the Coal Measures. In each case the underlying mass contains thin beds of coal, and is part of the whole series, distinct yet not separate. No one would think of placing the Conglomerate and the Coal Measures in different periods, much less in different ages.

Thirdly, That the conditions observed in the Great Lignitic Group, are but a repetition or continuation of those commonly observed in the Lower Cretaceous and less frequently in the Middle Cretaceous. The sandstones of the Lower Cretaceous, when unaltered, can hardly be distinguished from those of the Lignitic series; coal beds occur at both horizons; while on the Pacific Coast coal beds frequently occur in the Middle Cretaceous.

Fourthly, That the fauna consists for the most part of marine or brackish-water species. At the base of the series, in the great sandstone (including No. 5), the species are all marine; among the coal beds they are usually brackish-water, while at the highest horizon found in Colorado and New Mexico, they are marine. Here and there the fauna is a mixed one, and at times, over no inconsiderable area, it consists solely of fresh-water forms. There would be room for surprise were it otherwise. A shore deposit, such as this must have been, would be exposed to the influence of salt and brackish water alternately. The slow subsidence might be interrupted so as to permit the silting up of portions of the area, where fresh-water ponds of considerable extent might be formed. Such evidently was the case during the formation of the Coal Measures. Dr. Dawson has found a mixed fauna in the South Joggins Coal Field, and Mr. Meek obtained shells, closely allied to *Pupa*, from the upper coals near Wheeling, W. Va. Unfortunately our knowledge respecting the distribution of land and fresh-water forms during geological time is so limited that we cannot trace out the history of genera with any degree of satisfaction. No positive argument, bearing upon age, can be based upon their presence in any group of rocks.

Fifthly, That the fauna, wherever found, is Cretaceous, or of such a character, as to render it neutral testimony, affecting the issue neither in one direction nor the other. Throughout a large portion of the area the fauna is lacking. That barren zones occur in the Upper Cretaceous was observed years ago, by Dr. Hayden, in the Upper Missouri Region. The same is true of it throughout the whole Rocky Mountain Region, north from New Mexico. But we must determine fauna by what we have, not by what we have not. This we do in the Coal Measures, where the barren zones are quite as remarkable as those of the Upper Cretaceous in the Rocky Mountain Region. In the Anthracite area, animal remains are rare; in West Virginia, south from the Baltimore and Ohio Railroad, where the Coal Measures are exposed to a thickness of not far from two thousand feet, there is not a single stratum which is fossiliferous; and in the northern portion of the Great Bituminous Group, where the Coal Measures are nearly three thousand feet thick, there are but two strata, which persistently contain the fauna. Yet west from the Cincinnati axis, over a vast area, animal remains occur profusely at numerous horizons in the series.

A similar condition seems to have existed during the formation of the Lignitic Group. Near the old shore line, animal remains are rare, but as we pass from that line, they become more numerous. It should be re-

membered, that at no great distance from the mountains, this group is no longer within reach, having been removed by erosion, or buried under later deposits. Let us look at the succession of the whole series, Cretaceous and Lignitic, in New Mexico and Colorado :

New Mexico.	*Colorado.*
1. Bright-yellow to red and gray sandstones, more or less conglomerate and concretionary, with lignites, containing many mollusks, and *Halymenites major* throughout.	1. Same as in New Mexico.
2. Shales, limestones, variegated marls, some of the shales sandy.	2. Same as in New Mexice.
3. Bright-yellow to gray sandstones with shales and lignites.	3. Same as in New Mexico.

No. 2 is the Middle Cretaceous representing Nos. 2, 3, and 4 of the Upper Missouri Group, while No. 1 represents the Lignitic Group and Cretaceous No. 5. There is no difficulty in proving the identity of the two sections; it is simply a matter of tracing. In the New Mexico region, Dr. Newberry found at occasional exposures many characteristic Cretaceous species, while in its uppermost layers, Prof. Cope found a rich profusion of specimens.

East from the mountains, at rare localities, Dr. Leconte, in Colorado, and Dr. Hayden, further north, have found Cretaceous species in the lower portions, while in the topmost portions Mr. Arnold Hague and myself have found a grand profusion of species characteristic of Cretaceous No. 5. Far in the interior, Messrs. Meek and Bannister have found the undoubted Cretaceous forms at various horizons in the series.

Sixthly, That there is an utter lack of any positive evidence to show that the series is of later date than the Cretaceous. This statement may seem strange in view of Mr. Lesquereux's very emphatic assertion that the flora proves Tertiary age beyond all doubt.

The reasons given in a previous portion of this paper, are certainly sufficient to show that, in our present stage of knowledge, the testimony of plants can have no bearing upon the discussion. If a witness be shown utterly unworthy of credence in an important case, he certainly cannot be received as trustworthy in a similar and equally important case. *Falsus in uno, falsus in omnibus.* We have seen already that the plants showed the Dakota Group to be Miocene, and the Vancouver Coals to be of the same age. Yet everybody concedes that their testimony was invalid in the former instance, and everybody, excepting Mr. Lesquereux, concedes the same in the latter case.

But Mr. Lesquereux points out that the flora of the Great Lignitic Group is very different from that of the Dakota Group. This is not won-

derful. There would be room for wonder if the upper flora were not very different from the lower one, since the length of time represented by the Middle Cretaceous must have been enormous. Its rocks are limestones, fine shales, and very fine grained sandstones. These certainly were not deposited in haste. What changes in the vegetation were going on during this great period, we have no means of ascertaining, for not a leaf remains to tell the story. We know only that great changes did take place during the interval, since after its close the forms are different from those prevailing before its beginning. But it is very difficult to see how this difference in character is an argument to show that the rocks are Tertiary and not Cretaceous.

But the plants of this group are insufficient witnesses. Their testimony is as bad as that of the Dakota plants. The fucoid, *Halymenites major*, which Mr. Lesquereux does regard as diagnostic of the Tertiary,* is not a Tertiary fossil. It is Cretaceous or nothing, for whenever it is associated with a marine fauna, whether in New Mexico, Colorado, or Utah, that fauna is Cretaceous. Mr. Lesquereux acknowledges this as satisfactory evidence in one part of the series—why not in the other? The land plants are in some instances so eccentric in their range as to be of little service. In the Rocky Mountain region there are found seven species which occur also at Nanaimo. Their distribution in the Rocky Mountain region is as follows, according to Mr. Lesquereux :

Sequoia Langsdorfii, A. Br.	Lower Eocene,	Upper Miocene.
Salisburia polymorpha, Lesqx.,		Upper Miocene.
Sabal Grayana, Lesqx.,	Lower Eocene.	
Populus mutabilis, A. Br.,	Lower Eocene.	
Cinnamomum Heeri, Lesqx.,	Dakota Group.	
Andromeda Grayana, Lesqx.,	Lower Eocene,	Upper Eocene.
Diospyros lancifolia, Lesqx.,		Upper Eocene.

So in the Rocky Mountain region we find the Nanaimo species floating about from the base of the Cretaceous to the top of the Miocene. No doubt the distribution of these species shows that the Nanaimo beds and the Rocky Mountain beds are on the same horizon, and that they are both Lower Eocene as Mr. Lesquereux would have us believe. If they do, the fact must be taken by faith and not by sense.

As already stated, the occurrence of fresh-water shells or of land shells in any portion of the group is not satisfactory evidence, either for or against the Cretaceous or Tertiary age of the deposit.

In view of these facts,

1st. That the series above Cretaceous No. 4, to the top of the Great Lignite Group, is conformable within itself throughout,

2d. That no change of importance occurred in the general conditions during the formation of this series,

* See his remarks on "Coalville" in Hayden's Report for 1872, p. —.

3d. That the Cretaceous from the beginning was a lignite-producing period,

4th. That the fauna, whenever of a character to be compared with known standards is Cretaceous, even to the top of the series,

5th. That the hypothesis that this group or any portion of it is Tertiary is unsupported by definite evidence,

I am compelled to regard the Great Lignitic Group as Cretaceous, simply a renewal of the conditions marking the period of the Dakota Group.

ON THE REMAINS OF POPULATION OBSERVED ON AND NEAR THE EOCENE PLATEAU OF NORTH-WESTERN NEW MEXICO.

By E. D. Cope.

(*Read before the American Philosophical Society, June* 18, 1875.)

While encamped on the Gallinas Creek, at the point where it issues from the Sierra Madre, with the party detailed by Lieut. Wheeler for purposes of geological exploration, I occupied intervals of time in the examination of the traces left by the former inhabitants of this portion of New Mexico.

Had time permitted, the exploration of these remains might have been much extended, but under the circumstances a mere beginning was made. The observations show that the country of the Gallinas, and the Eocene plateau to the west of it, were once occupied by a numerous population. Now, there are no human residents in the region, and it is only traversed by bands of the Apache, Navajoe, and Ute Tribes of Indians. The indications of this ancient population consist of ruined buildings, pottery, flint implements, and human bones. Broken vessels of baked clay are frequently found, and the fragments occur in all kinds of situations throughout the country. They are usually most easily discovered on the slopes of the hills and hog-backs of Cretaceous and Tertiary age, and where abundant, generally lead to a ruined building standing on the elevation alone.

The hog-back ridges which I have described in my geological report, extend in a general north and south direction on the western side of the Sierra Madre, south of Tierra Amarilla. They vary from two to four in number, and stand at distances of from half a mile to three miles from the mountain range. The Gallinas Creek flows between two of them near their southern extremities for perhaps fifteen miles. At one point the hog-backs of Cretaceous Nos. 3 and 4 approach near together, and the creek flows near to the foot of the eastern front or escarpment of No. 3. The rock of this ledge is a hard sandstone, and resists erosion hence its outcrop forms continuous sharp ridges, with distant interruptions, which are termed by the Mexicans the Cuchillas or Cristones. The hog-back of No. 4, being composed of softer material, is worn by erosion into a succession of sub-conical eminences.